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The nudibranch family Dironidae.

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With Plates 30-32.

Among the various Opisthobranchs collected and studied by the writer on the Californian Coast the two which form the subject of the present paper are among the most interesting. Their characteristics set them apart so definitely from the other families of the group that it seems necessary to propose a new family for their reception. A brief description of some features of one of them has been given by Sir CHARLES ELIOT (1905), based upon the study of a single specimen, collected by Prof. T. D. A. COCKERELL at San Pedro, California, and aided by memoranda by the present writer. In his masterly Supplementary Part VIII to ALDER and HANCOCK'S British Nudibranchiate Mollusca ELIOT (1910) has again recognized the separate position of the *Dironidae*, the justice of which will, I think be evident to those who read the following pages. The limitations of space, however, prevent a complete treatment of the morphology of this group and many points of interest must be reserved for a future publication.

The material has been collected at various times in the neighborhood of Pacific Grove, California, while enjoying the facilities of the Marine Biological Laboratory of Stanford University there. My thanks are due to the Directors, Professors GILBERT and JENKINS, for these continued privileges. To my wife I am especially indebted

for the illustrations of the present paper, and for constant assistance in the preparation of microscopic sections.

Types of the two new species here described are deposited in the Museum of Invertebrate Zoology of Leland Stanford Junior University, and co-types will also be placed in the National Museum at Washington, D. C.

Dironidae MACFARLAND *Fam. Nov.*

Body aeolidiform, the foot wide, rounded in front, the tail pointed; oral tentacles absent; head with a large veil; cerata without cnidosacs, closely arranged along the sides of the dorsum and extending forward toward median line in front of rhinophores. Liver lobulate, without branches extending into the cerata; rhinophores perfoliate, without sheaths; anus on right side near posterior end of body.

Mandibles very large, the masticatory margin smooth. Radula teeth in five transverse rows.

Dirona, MACFARLAND *Gen. Nov.*

Dirona MACF. MS., ELIOT in COCKERELL and ELIOT, Notes on a Collection of Californian Nudibranchs, in: Journ. Malacology, 1905, Vol. 12 (3), p. 45. The British Nudibranchiate Mollusca, Part VIII (Supplementary), 1910, p. 69.

Body broad, sub-depressed; head bearing a broad thin veil with smooth, undulating margin, in width equal to, or wider than, the foot; no oral tentacles; rhinophores perfoliate, non-retractile within sheaths; cerata large, inflated, non-caducous, arranged irregularly along margin of dorsum in a closely set series, which extends nearly to median line in front of the rhinophores. Cerata of varying size, the largest usually innermost, with smaller ones external to their bases; cnidosacs absent. Liver lobulated, but with no ramifications to the cerata. Foot broad, rounded in front, tapering behind to a short tail. Anus at the summit of a conspicuous papilla far back, on right side, just below the cerata.

Lip disk covered with thick-set, hair-like cuticular processes. Mandibles massive, the masticatory surface smooth, formed by a shield-like expansion which is reflected over the anterior margin of the mandible.

Radula narrow, its formula 2·1·2, the median tooth small, the

laterals widely separate from it. First lateral depressed, of moderate size, denticulate on inner face, second lateral large, compressed, simply hamate.

Dirona picta MACFARLAND *Sp. Nov.* (and Genotype).

(Plate 30 Fig. 1, Pl. 31 Figs. 1—10, Pl. 32 Figs. 20, 22—24).

Dirona picta MACFARLAND, ELIOT in COCKERELL and ELIOT, Notes on a Collection of Californian Nudibranchs, in: Journ. Malacology, 1905, Vol. 12 (3), p. 46—48, Pl. 7, figs. 6—11.

Body form stout, somewhat limaciform, abruptly rounded in front, posteriorly tapering to the tip of a rather short tail. Dorsum slightly rounded, sloping rapidly behind the heart region, less so in front. Head broad, squarish, its margin expanded into a broad, undulating veil. Foot elongate, bluntly rounded in front, squarish, tapering posteriorly to the short tail, which is about one third of the body length.

Rhinophores without sheaths, directed forward and outward, clavate, the clavus irregularly perfoliate, one-third to one-half the length of the whole organ. Cerata lanceolate, inflated, slightly flattened antero-posteriorly, non-caducous, arranged in closely-set irregular series along each side of the dorsum, converging in front toward the median line, but not meeting, thus leaving a small area free from cerata. Cerata rows meeting posteriorly above tail. Inner surface of the cerata tuberculate, the elevations often being confluent into a median longitudinal ridge with short irregular branches. Outer surface less tuberculate. Largest cerata one-third to one-half the length of the animal, innermost in position, the shorter ones arranged externally to them. Cerata not containing branches of the liver.

Reproductive openings two, not conspicuous, situated as usual in Aeolidiadae. Renal opening close up to outermost cerata a short distance behind the reproductive openings. Anal opening at the summit of a conical papilla, far back on the right side, in the line of the outermost cerata.

Color (Pl. 30 Fig. 1) reddish yellow to brown, the dorsum sprinkled everywhere with fine yellowish-white, olive green, and pink spots. In the middorsal and lateral region the dark olive green liver shows conspicuously through the integument.

Total length up to 40 mm, width 7 mm, height 7 mm.

Mandibles strong and massive, the hinge region and grinding surface deep, reddish amber, the wing paler. Lateral wing thick, somewhat triangular, its dorsal border straight, the posterior and ventral borders rounded. The upper portion of the wing is thickened, its outer surface convex, the inner surface convex above, somewhat concave below. Upon the anterior inner surface is borne a shield-shaped plate, reflexed outward in front and forming the smooth, or slightly roughened masticatory surface. Above the mandibles are hinged together by a strong ligament in front, and immediately behind it by a chitinous band, triangular in cross section.

Radula formula $2 \cdot 1 \cdot 2 \times 32-35$. Rhachidian tooth small, at the bottom of a deep median groove, widely separated from the laterals. Its base strong, squarish, notched in front, rounded behind, bearing a single, median spine directed obliquely upward and backward. First lateral larger, strongly depressed, its base elongate, linear, with rounded ends, bearing a single, strong spine, which is slightly curved, and bears on its inner face, near the base a series of from six to seven denticles, at times extending well up along the side of the spine. Outer lateral large, hamate, strongly compressed, its base long and curved, the tip of the hook blunt. The tooth is placed very obliquely on the upper margin of the radular groove, and is attached along the lower side of the base, instead of at its bottom.

Glans penis short, conical; spermatheca very small; oviduct long and wide.

Habitat: Southern shore of Monterey Bay, California, and adjacent coast line, also taken as far south as San Pedro, California. In littoral zone, on rocky places, crawling on the brown algae, or, in quiet water, often floating, the sole of the foot uppermost, at the surface. Abundant during the summer months.

Dirona albolineata MACFARLAND *Sp. Nov.*

(Plate 30 Fig. 2, Pl. 31 Figs. 11—19, Pl. 32 Fig. 21.)

Body somewhat limaciform. everywhere smooth, tapering from the bluntly rounded head to the tip of the short, pointed tail. Head broad, squarish, bearing a broad, undulating veil, no labial tentacles. Foot elongate, broad and rounded in front, tapering posteriorly, its anterior margin smooth, undivided, slightly thickened.

Rhinophores without sheaths, directed forward and outward, the

clavus conical, deeply perfoliate, about one-half the length of the whole rhinophore. Cerata lanceolate, inflated, entirely smooth, somewhat flattened antero-posteriorly, arranged in closely set, irregular series along each margin of the dorsum. The largest cerata are innermost and may reach one-fourth to one-half the length of the animal, smaller ones are arranged externally to these in close, but irregular series. Cerata continued forward in front of the rhinophores toward the median line of head but do not meet. The two lateral series meet posteriorly above the tail. No cnidosacs present. No branches of the liver extending into the cerata.

Reproductive openings two, situated as usual, inconspicuous. Renal opening minute, immediately below the cerata, a short distance behind the reproductive openings. Anal opening at summit of a cylindro-conical papilla, far back on right side, in the line of the outermost cerata, near the posterior end of the body.

Color (Pl. 30 Fig. 2) everywhere a beautiful translucent grey, save for a narrow band of pure white edging the veil, the lateral margins of the cerata, the median crest of the tail, and passing from the inner base of the clavus of each rhinophore down the inner side of its stalk and uniting in a transverse line across the head. Along the upper, right side, just below the bases of the cerata and extending from immediately behind the reproductive openings to the posterior end of the dorsum is a broad, whitish band, conspicuous in alcoholic material, due to a strongly developed glandular zone. In large individuals the body and cerata are occasionally also flecked with minute spots of pure white. The dark liver shows through the integument.

Total length up to 42 mm, height 8 mm, width 7 mm.

Mandibles strong and massive, in general similar to those of *Dirona picta*, the boundary between the upper and lower portions of the inner face of the wing being less strongly marked.

Radula formula $2 \cdot 1 \cdot 2 \times 29 - 32$. Teeth similar in form to those of *Dirona picta*, but the laterals much larger. Median tooth almost rudimentary, at the bottom of a deep groove, its base rounded in front, squarish behind, in side view triangular, its upper surface prolonged into a straight spine, which is often finely grooved on its upper surface. First lateral tooth depressed, nearly horizontal. Base elongated, nearly linear, the ends rounded, above prolonged posteriorly in a stout spine, which rises but slightly above the plane of the upper surface of the basal portion. Upon the inner basal

margin a series of from two to four short, pointed denticles. Second lateral large, hamate, very much flattened, borne obliquely upon the margin of the radula groove, the tooth being strongly inclined, through its base being attached on its inner, lateral surface. Base long and slender and much curved to conform to the surface to which it is attached. Hook simple, strongly curved, blunt.

Glans penis large, with thick-set papillae on sides. Spermatheca large; oviduct slender and short.

Habitat: Southern shore of Monterey Bay, California, and adjacent coast line, in tide pools of the littoral zone. Very rare.

General Morphology of the *Dironidae*.

Owing to the relative scarcity of *Dirona albolineata* and the abundance of *Dirona picta* anatomical studies have been confined, in the main, to the latter species. No attempt will be made here to give a complete account of the morphology of these interesting animals as that would necessarily exceed the limits of the present paper. Only the most striking features which justify their separation as a distinct family can be taken up here.

The general body form is practically the same in both species (Pl. 30 Figs. 1, 2), broad and but slightly flattened. On preservation in alcohol the form becomes markedly prismatic through shrinkage, resembling the Tritoniadae. The dorsum slopes rapidly forward and backward from the heart region. The head bears a broad velar expansion with an undulating margin. No trace of labial tentacles can be made out, though the velum is to be regarded, probably, as formed by a fusion of such structures. The anterior end of the foot is simply rounded, thickened, and undivided. Its increased thickness is due to the very large development of the glandular epithelium which everywhere characterizes the foot.

The rhinophores are tall organs, arising from just within the inner row of cerata on the head, and are directed outward and forward. The clavus is conical, one-fourth to one-half the length of the whole organ. In *Dirona albolineata* (Pl. 32 Fig. 21) the clavus is regularly and deeply perfoliate, with about 16 to 20 leaves, united in front and behind in a median ridge. In *Dirona picta* (Pl. 32 Figs. 22 and 23) the clavus is of similar shape, but the perfoliation is irregular, the laminae being branched.

Along the margins of the back at their junction with the sides, are borne the cerata, large inflated structures, with pointed apices,

and slightly flattened antero-posteriorly. In *Dirona picta* they are roughened with tubercles, notably on the inner surface where these elevations form a longitudinal ridge with a series of irregular branchings extending laterally from it (Pl. 30 Fig. 1). These elevations contain blood vessels close beneath their surface, and are probably of respiratory significance. In *Dirona albolineata* the cerata are smooth throughout. Each cера is made up of a loose connective tissue framework, covered externally by a continuation of the low, columnar epithelium which clothes the general surface of the body. Two longitudinal blood vessels, an external and an internal, connected with each other by abundant lateral branches, which course near the surface, are found in each cера. The outermost of these connects with a large, longitudinal sinus at the base of the cerata rows, and receives blood through it from the general body sinuses. The inner vessel, receiving the numerous superficial branches contained in the surface ridges, connects with an inner dorsal, longitudinal trunk passing directly to the auricle. At the base of the cера each of these trunks is provided with a well developed sphincter muscle by which the lumen may be closed in case of the accidental loss of such an exposed and delicate structure. Through these muscles the relative distension of the cера with blood may also be controlled. Thus the cerata are definitely respiratory in function, sharing this, however, with the general body surface. Each cера is provided with muscle fibres radiating into it from its base and attached at their proximal ends to the adjacent body wall. Other fibres pass in various directions through the cера and accomplish its different movements. An abundant nerve supply is furnished by branches of nerves from the pleural ganglia, which form complicated anastomoses within the organ, including in their course a large number of small peripheral ganglia. The terminal fibres are distributed to the integument and to the muscle fibres.

In the posterior half of the body there extends forward, just below the bases of the cerata, along the upper margin of the side of the animal, a narrow, glandular band, which, in *Dirona picta*, encircles the posterior end of the dorsum, extending forward on each side of the animal to about the same distance. In *Dirona albolineata* this band appears to be limited to the right side, or at least is much better developed there. It extends forward to the region of the reproductive openings, and is made up of a densely packed mass

of epithelial gland cells. What its significance may be is at present unknown.

Alimentary system. The mouth opening is surrounded by soft fleshy, glandular lips leading into a very short oral tube or vestibule. Within this the inner lip disc, covering the anterior opening of the pharynx, is seen. It is circular in outline, with an elongated vertical opening. Immediately in front of this disc the epithelium develops a cuticle which thickens as the disc is approached, and, upon it, becomes greatly increased and split up into a mass of densely set, hair-like processes, each one of which, in its basal portion corresponds in width to a single epithelial cell. The distal ends of these cuticular hairs are frayed and worn, and in some instances appear to be split into further fine terminal divisions. They reach a length of 0,4 mm, the basal diameter being 0,003 to 0,005 mm, the height of the cell producing them reaching but 0,021 mm. The action of KOH causes the lip disc to fall apart completely, save at its peripheral portion, where the cuticle is continuous. This labial fringe would completely cover the mouth opening whenever the circular constrictor muscle of the lip disc is contracted.

The pharyngeal bulb is very large, often making up from one-third to one half the whole bulk of the viscera. The mandibles are massive, amber structures, departing markedly from the usual type found in the Aeolidiadae. Their form can best be understood by a reference to Figs. 5 and 6 of Plate 31, which represent the outer and inner surfaces of the mandibles of *Dirona picta*, and to Figs. 17 and 18 of the same Plate, which show similar views for *Dirona albolineata*. Instead of the usual relatively thin concavo-convex wing portion, with a thicker articular region and a masticatory process in front, the wing here is thick and strong (*w*), its outer surface is convex, the inner surface convex dorso-ventrally, and somewhat concave in an antero-posterior direction. The right mandible is often slightly shorter than the left, though the difference is not very marked. In both species the wing region is of a light, translucent amber color, while the hinge region and the grinding surface are of a very dark reddish hue. The outer surface of the wing is convex with a slight groove radiating from the hinge region in both species. Upon the convex, inner face a sharp longitudinal ridge in *Dirona picta* (Pl. 31 Fig. 6) marks the dorsal boundary of the large ventral adductor muscles which are inserted upon the whole of the wing of the mandible below this line, while above it this space is

occupied by the radula and its cartilages. In *Dirona albolineata* (Pl. 31 Fig. 18) this ridge is much less strongly developed, though the same muscle relations exist.

The dorsal margin of the wing is straight, the posterior and ventral ones curved. On the anterior, inner surface is borne a broad, thick, shield-like plate (Pl. 31 Figs. 5, 6, 17, 18, *m*), continuous with the thickened, inner surface behind and above, and reflected across the front margin of the mandible. This masticatory plate is strengthened in its attachment by three radiate thickenings of the mandible which are best seen by transmitted light and are shown in the outline drawing of Fig. 7, *1, 2, 3* of Pl. 31, which represents the outer surface of the right mandible of *Dirona picta*. The uppermost of these extends along the dorsal border of the wing, the lower extends obliquely from the lower portion of the wing upward toward the hinge region, while the anterior one is a thickening along the masticatory surface itself. It is to be understood that these do not appear as elevations upon the surface alone, but are denser, more compact regions of the mandible substance, which are evident by transmitted light. The three thickenings center in the region of the fulcrum of the mandible, which is especially thick and massive, and bears the hinge uniting the lateral halves together. This hinge is made up of two portions, an anterior ligament, optically distinct from the mandible substance (*h*), and a posterior, triangular chitinous band (*c*), which is a direct continuation of the mandible substance on either side. The upper surface of this chitin band is deeply grooved, presenting a V shape in cross section as shown in the cut surface *c* of Figs. 6 and 18 of Pl. 31. This groove is continued downward on the external face and merges into the dorsal surface of the mandible. The posterior wall of this groove is prolonged into a thin expansion extending obliquely upward and backward. The plate thus formed furnishes a support for the roof of the anterior pharyngeal cavity, and above it is situated the flat transverse band of muscle which opens the mandibles.

The masticatory surface is slightly hollowed in its central portion and roughened irregularly. Other than this it is entirely smooth, with no trace of a denticle armature so common in other Aeolids. The only mandible in any way resembling that of *Dirona* is that described by VAYSSIÈRE (1903) for *Madrella aurantiaca*, which species differs widely from *Dirona* in all other respects.

The radula, radula sack, and rotella are situated in the

extreme upper portion of the space between the mandibles, all the lower two-thirds being occupied by a powerful transverse adductor muscle, which binds the mandibles together below. The fibres of the lowermost portion of this muscle are directly transverse, while the remainder is made up of two distinct sets of fibres, arranged separately and crossing each other at a slight angle. The alternate contraction of these different muscle fibres would give the masticatory surfaces of the mandible a grinding motion upon each other, for which their shape is admirably adapted.

The short, tubular radula sack is horizontal, the active portion of the radula being curved downward in front. The radula is deeply grooved in its anterior portion, and bears five transverse rows of teeth, the median row occupying the bottom of the groove, and widely separated from the lateral rows, which are borne just within, and upon the crest of the groove respectively.

While the teeth of the two species are of the same general form, the teeth of *Dirona albolineata* are decidedly the larger, as may be seen by a comparison of Figs. 1 with 11, 4 with 19, and 10 with 14 of Pl. 31, all of which are drawn at the same magnification. The average differences in size may also be gathered from the following table, though some slight variation is to be expected in different regions of the radula.

	<i>Dirona picta</i>	<i>Dirona albolineata</i>
Median tooth:		
Total length	0,060 mm	0,072 to 0,080 mm
Length base	0,037	0,048 to 0,050
First lateral:		
Total length	0,168	0,198 to 0,216
Length base	0,114	0,138 to 0,198
Length hook	0,054	0,06 to 0,078
Second lateral:		
Length base	0,198	0,210 to 0,228
Height hook	0,126	0,132 to 0,168

The first lateral tooth of *Dirona picta* (Pl. 31 Figs. 8, 9, 10) bears a series of small denticles, four to seven in number, on its inner basal surface, while the similar tooth of *Dirona albolineata* (Pl. 31 Fig. 13, 14, 16) bears at most but four such denticles. I have been unable to find any trace of the rudimentary denticles upon the base of the median tooth as described by ELIOT (1905).

The second lateral tooth (Pl. 31 Figs. 4, 19) is very large with a long basal portion and a simple, strong and blunt hook. The tooth is strikingly flattened throughout, and is borne at the crest of the sides of the median groove, the position of the base being quite oblique to the long axis of the radula. The surface of attachment is also quite oblique to the plane of the tooth, so that in sections it appears to be almost lying upon its side, the tips of the hooks converging toward the median line and interlocking above the groove. The epithelium of the roof of the pharynx forms a median and several smaller lateral folds, and is covered by a thick cuticle.

The esophagus emerges from the upper surface of the pharyngeal bulb, midway of its length, immediately above the middle of the radula, and is encircled at once by the central nervous system. The slender ducts of the salivary glands pass through this loop, enter the esophageal wall and pass forward in it to a point opposite the anterior end of the radula, where they open into the buccal cavity near the posterior ends of the masticatory surface of the mandibles. Upon the posterior portion of the esophagus the ducts pass into the broad, lobulated salivary glands.

The short and rather wide esophagus passes backward and downward and, at the anterior margin of the posterior visceral complex, dilates into the thin-walled stomach. This organ occupies the anterior portion of the complex, its lower face in contact with the inner surface of the foot, the left side almost, and the right side entirely concealed by the lobes of the liver. In shape it is quite similar to the mammalian stomach, the greater curvature being directed downward and backward, while the pyloric portion is recurved above the anterior and middle region, thence being continued forward as the intestine. Upon the upper anterior surface of the visceral complex the intestine describes a loop to the right and passes obliquely downward and backward to the ventral surface of the complex, along which it passes in a gentle curve to the left, terminating in the rectal portion and the anus at the extreme posterior end of the complex. Thus the intestine is exposed along the upper, right and lower faces of the complex through its whole extent, while the stomach is covered by the lobes of the liver and the hermaphroditic gland, save at the anterior face of the complex. Its pyloric end and a small area on the left side.

The wall of the esophagus is thick and muscular and is folded longitudinally, while that of the stomach is thin and smooth. The

lining of the esophagus is made up of high columnar ciliated cells, while that of the stomach is much lower and for the greater part is likewise ciliated. No trace of anything resembling a gastric armature can be found, and the small spines observed by ELIOT (1905) are undoubtedly foreign material. Into the stomach about midway of its length open the two wide ducts of the liver lobules, one the more anterior, upon the upper, right side, the other, midway of the left side in the upward curvature of the organ. The liver is lobulate, but the lobules are limited to the visceral complex and present smoothly curved external surfaces, there being no trace of any ramifications extending into or even toward the cerata, such as are found in nearly all other Aeolidiadae. Four principal lobes may be distinguished, which are in turn more or less clearly subdivided into lobules. These are the following.

1. Antero-dorsal lobe, situated upon the left anterior end of the visceral complex. Its convex external surface is triangular, it being wedged in between the anterior end of the stomach, its pyloric end, and the beginning of the intestine. At its posterior end it opens into the stomach by a broad duct, which also receives the duct of the posterior lobe of the liver.

2. Posterior lobe. This largest division of the liver is approximately pyramidal in form, the obliquely concave base being directed forward and in contact with and overlapping the posterior portion of the greater curvature of the stomach. The apex is bluntly rounded, and forms the posterior end of the visceral complex. The posterior lobe is in turn divided into four lobules, one of which, the more dorsal and anterior, is clearly separate from the remainder, its duct, however, joining the main duct of the lobe. The antero-ventral lobule is less clearly marked off externally, while the two posterior lobules appear to be fused, until carefully separated, when each is found to have a separate duct, all uniting together into one main posterior duct which opens as above described.

3. The dorsal lobe of the liver lies in the upper anterior portion of the visceral complex, and bears a deep, transverse groove in which the anterior loop of the intestine lies. Its ventral face rests upon the upper and right side of the stomach, into which it opens by a wide duct on the upper right side, which is also joined by the wide duct of the remaining lobe.

4. The ventro-anterior lobe lies obliquely across the lower anterior face of the visceral complex. Its right border is in con-

tact with the intestine, its posterior and left borders and dorsal surface with the stomach. Its duct joins the duct of the dorsal lobe as the latter enters the stomach.

The cells of the liver are cubical and vacuolated, with compact, dark nuclei. Granular inclusions of several kinds are numerous, but no detailed cytological study has been made of their nature. In life the liver has a dark green color, but to what this may be due has not been determined.

The intestinal wall is thin with a slightly developed muscular layer. Its inner surface presents numerous longitudinal ridges, and is covered with a layer of columnar ciliated cells, which continue uninterruptedly to the canal opening. In the finely divided contents of the alimentary canal but little can be distinguished save diatom shells and minute spicules. These make up a very small proportion of the total contents.

Excretory system. The kidney is a thin-walled sac lying immediately beneath the pericardium on the dorsal surface of the visceral complex, and sending complicated ramifications over its surface, and down in the interstices between the lobes of the hermaphroditic gland, the liver and the alimentary tract. These branches are irregular in form and terminate in slightly dilated tips. They are lodged in the loose connective tissue, so that with some care the whole organ may be dissected out from its attachments and isolated. Two main superficial branches may be distinguished, extending from the central elongated chamber. One of these passes transversely toward the left side, enveloping the anterior region of the visceral complex and extending laterally down to the foot. The second branch passes backward and ramifies over the posterior median and lateral surfaces. Two other branches of unequal size, and several minor ones arise from the central surface of the ventral chamber and pass downward between the organs of the visceral complex. The largest of these is directed downward and backward, following the hermaphroditic duct, while the smaller passes downward toward the left, and forward between the stomach, the liver lobes and the proximal intestine loops. The reno-pericardial opening is found in the renal syrinx, a conspicuous pyriform body situated midway of the animal's length, upon the right dorsal surface of the visceral complex. It communicates below with the cavity of the kidney, and above with the pericardial cavity, opening through the floor of the right side. Its lumen is divided by numerous folds of the wall, many of which in turn bear secondary folds. The complicated

opening thus formed is lined in its upper portion by high columnar cells, bearing very long cilia, which are directed downward. The kidney itself is everywhere lined with small cubical cells, each with a large distal vacuole. A small area of dense protoplasm surrounds the basally placed nucleus. The general structure of the kidney agrees with the descriptions given by HECHT (1896) for the Nudi-branch kidney. The external opening, the renal pore, is located immediately below the outer row of cerata on the right side, a short distance behind the genital opening, and but slightly behind the level of the renal syrx. Externally it is a minute pore which may be easily overlooked. Histologically it is lined by a low ciliated epithelium, replacing the renal cells within, and passing over into the general epithelium of the body wall at the margin of the pore.

Nervous system. The central nervous system of *Dirona* is of the general Aeolid type, and is represented for *Dirona picta* in Fig. 24 of Pl. 32, as seen in dorsal view. The buccal ganglia have been removed from their natural position beneath the cerebral pair, where they would have been entirely concealed.

The cerebral and pleural ganglia of each side are fused in a single mass, and are in close contact in the median line, being united in the anterior portion by a very short commissure. The antero-median portion of the cerebral moiety is prolonged into a bluntly pointed lobe, while its lateral portion is also widened out into lateral lobes. The pleural portion of the cerebro-pleural complex is more nearly spherical, as are also the pedal ganglia, which are closely united to the cerebro-pleural complex by the short cerebro-pedal and pleuro-pedal connectives. From the cerebral ganglia arise the following nerves, which are here designated in the same manner as in Fig. 24 of Pl. 32, to which reference should be made without further citation in the text.

c1, a strong nerve to the rhinophore ganglion. Near the base of the rhinophore it gives off a slender branch, which forks to the integument, and in it forms various anastomoses with other nerves in the same region.

c2 arises just outside of *c1*, passes forward and downward over the pharyngeal bulb and bifurcates, the inner ramus passing to the mouth region, the outer one to the veil.

c3 arises near *c2* and follows a similar course, bifurcating, the two branches having the same distribution as those of *c2*.

c4, a more slender nerve than *c3*, arises just external to the

latter and bifurcates, the internal branch passing to the retractor muscle of the bulb, the outer branch being distributed to the muscles of the mouth region.

c5, the slender optic nerve, arises from a small spherical ganglion, the optic ganglion, upon the postero-lateral margin of the cerebral ganglion. The nerve is closely attached to the anterior margin of *c6* (or *pl. 1*) a nerve which arises close behind and below the optic ganglion, and which it accompanies out nearly to the eyes, which are located immediately behind the rhinophores, below the integument.

c6 (or *pl. 1*) arises close to the pleuro-pedal connective in the angle formed by the union of the cerebral and pleural ganglia. Without careful reconstruction of serial sections it is impossible to determine its exact origin. DREYER (1910) identifies a similar nerve as arising from the pleuro-pedal connective and terms it a pleural nerve in several Aeolids, and I have described (1909) and figured for *Spurilla braziliana* a nerve of similar distribution and of undoubted pleural origin so that this nerve may be safely regarded as pleural likewise. It branches to the dorsal integument in the neighborhood of the rhinophores, and sends a branch to the retractor muscle of the pharyngeal bulb, the main branches however passing to the cerata of the head region and to the integument at their bases.

The otocyst rests upon the surface of the pedal ganglion in contact with the side of the cerebro-pleural ganglion, immediately behind the optic ganglion.

pl. 2, the second pleural nerve arises from the upper surface of the ganglion and breaks up into four main branches. The innermost of these passes backward near the median line to the integument of the pericardial region. The longest branch courses backward along the upper margin of the side, at the bases of the cerata, and gives off branches to these organs. The remaining two branches pass to the integument of the head region and also to the anterior cerata. In *Dirona albolineata* a slender branch of one of these subdivisions of *pl. 2* was traced forward to an anastomosis with a branch of the slender twig from *c1*, the rhinophore nerve, an arrangement similar to that termed by DREYER (1910) the "outer commissure". Such peripheral anastomoses are by no means of rare occurrence in Opisthobranchs.

c-b. c. From the ventro-lateral margin of the cerebral ganglia the short cerebro-buccal connectives arise and curve around under

the esophagus to the buccal ganglia, lying immediately beneath, just behind the point of exit of the esophagus from the pharynx. The buccal ganglia are shown in the lower portion of Fig. 24 of Pl. 32. The buccal commissure is relatively long and the ganglia thus widely separated. Two postero-ventral nerves pass directly into the bulb from the ends of the commissure to the muscles of the rotula. Numerous nerve cells are borne upon the nerves from this ganglion pair and the groups shown in the figure constitute probably the stomato-gastric ganglia, though other scattered nerve cells are found all along the nerves from the buccal ganglia, as well as in the immediate vicinity of these figured.

Three pairs of nerves arise from the pedal ganglia. These are. *p1*, the anterior pedal nerve, which arises from the ganglion at its outer anterior margin, divides into three main branches and is distributed to the anterior end of the foot.

p2, a large nerve on the right side, much smaller on the left. It arises from the outer anterior face of the ganglion, and on the left side is distributed to the median body wall and foot. On the right side it sends several branches which innervate the retractor muscle of the preputium, and the distal loops of the vas deferens, and the penis, together with the adjacent body wall.

Below the esophagus the ventral portion of the nerve collar is made up of the cerebro-buccal loop, the pedal (*p.c*) and the parapedal (*p.p.c*) commissures, and the pleural (*pl.c*) or visceral commissure. The pedal and parapedal commissures are united together in a broad band and constitute together the strongest loop. The pleural commissure arises from the postero-ventral face of the pleural ganglia and forms a loop around the esophagus of some length. It gives rise to a good sized unpaired genital nerve (*n.g*) from its right portion, and a pair of more slender nerves in addition, which are distributed to the viscera. These nerves have conspicuous ganglion cells at their origin from the commissure and scattered along their course.

Reproductive system. The hermaphroditic gland of *Dirona* is divided into six to eight hemispherical or prismatic lobes which are lodged among the lobes of the liver and the loops of the alimentary canal in the posterior visceral complex. Two of these lobes are visible upon the dorsal surface, near the median line, one in contact on its left with the pyloric end of the stomach, the other behind the same. Upon the right and ventral sides the remaining

lobes are visible beneath the posterior lobes of the liver, resting upon the ventral intestinal loop, and forming the lower posterior portion of the visceral complex. They are all connected by ducts which unite in a common slender hermaphroditic duct (Pl. 32 Fig. 20 *h. d*) passing forward and upward to the anterior genital complex. Here the duct dilates into the hermaphroditic ampulla (*h. a*) describing a double loop upon the posterior face of the complex, and, narrowing suddenly, bifurcates into the vas deferens and the oviduct. While the general arrangement of the anterior genital complex is the same for both species of *Dirona*, they present marked differences in detail. In *Dirona picta* the hermaphroditic ampulla divides into a very long vas deferens (Pl. 32 Fig. 20 *v. d*) and a quite long and greatly dilated oviduct. The point of division (*x*) is in close apposition to the inner face of the mucusalbumen glands, but the oviduct is entirely independent of the latter at this point. It dilates into a roomy tube, as large as or larger than the hermaphroditic ampulla, and is coiled in several loops upon the lower anterior face of the anterior genital complex, opening into the inner portion of the genital atrium (Fig. 20 *a*). By this term is designated a cavity, crescentic in cross section, immediately within the external female opening. The tips of this crescent are dilated and turned forward and upward. Following the upper, dilated portion of this channel inward from the external opening, the mouth of a slender duct is found, leading into a small, scarcely dilated, blind sack, the spermatheca, which lies upon the upper face of the genital complex. In Fig. 20 *s* this is represented as projecting freely above the albumen gland, and opening through the dorsal wall of the atrium. Just behind the opening of this duct is found the opening of the oviduct, and beyond and below that the opening of the albumen and mucus glands. The lower part of the crescentic channel corresponds to the duct of the accessory glands, and is undoubtedly the path taken by the egg band in oviposition, while the upper portion corresponds to the vaginal duct, occurring as a separate channel in other Nudibranchs. The almost rudimentary condition of the spermatheca in this species is a very striking feature, and can scarcely be explained as a condition due to sexual immaturity. The dilated oviduct seems to have assumed in part the function of a spermatheca, for it is frequently crowded with spermatozoa, while the spermatheca itself contains relatively few. The examination of

Dirona albolineata in this respect is of the greatest interest. Here we find a quite short and slender oviduct, extending almost directly from the point at which the vas deferens is given off to the atrium, opening into the latter at a similar point as in *Dirona picta*. The spermatheca, however, is very large, reaching a diameter of 1,3 mm its total length being 4 mm in a large specimen, which is over four times the corresponding dimensions in *Dirona picta*. The anatomical relations of the spermatheca are exactly the same in the two species.

Equally striking differences in the relative development of the same organs are found in the male branch of the hermaphroditic duct. In *Dirona picta* the vas deferens is very long, often longer than the whole animal itself. In it may be distinguished a proximal glandular and a distal muscular portion. It is wound in a complicated series of coils upon the upper anterior portion of the genital complex. Its distal portion at first gives one the impression of being an organ of considerable bulk, but closer examination shows that this is largely due to an enclosing sheath of muscle fibres, the retractor muscle of the preputium. These arise from the left wall of the body, extend across in front of the posterior visceral complex and are inserted around the preputial portion of the vas deferens, inclosing the closely coiled, distal loops of the duct, and thus appearing to constitute a bulky organ. When separated, however, the tube is found to be long and slender, the small conical glans being borne at the inner end of a preputial tube, 4,0 mm from its outer opening. The inner wall of this preputium, which becomes the external surface of the intromittent organ when everted, is ridged in a somewhat spiral manner, giving the appearance of an armature.

In *Dirona albolineata* the vas deferens is much shorter. It shows also the divisions into a glandular and a muscular portion. The preputial region presents the most striking differences. Here it is a large, roomy sack, with a strong cone of muscles inserted in its proximal portion. At its inner end is borne a very large cylindro-conical glans, blunt at the extreme tip and bearing on its surface a very large number of conical eminences, apparently arranged in a spiral row of very close turns. These structures resemble an armature but there is no trace of a corresponding cuticular thickening to form spines. The glans fills up the whole length of the preputial sack, and is often bent upon itself in addition, which con-

dition may of course have been caused by distortion produced in the preservation of the animal. In the largest individual dissected the glans was 3,5 mm long and 0,7 mm in diameter while in a second individual it was 2,4 mm long and 0,32 mm in diameter. In *Dirona picta* the greatest length found was 0,96 mm, the diameter being 0,08 mm.

The remaining portions of the anterior genital complex consists of the mucus and albumen glands (Fig. 20, *n, a*), which present much the same features in both species. They are compact bodies, the albumen gland resting in a depression upon the surface of the mucus gland. The excurrent duct is large and forms the lower portion of the genital atrium before described.

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Explanation of Plates.

All of the figures of Plates 30—32, with the exception of Fig. 2 of Plate 30, were drawn by Mrs. OLIVE H. MACFARLAND. Fig. 2 of Plate 30 was drawn by Mrs. LOUISE B. NASH. The ABBE Camera Lucida was used in all drawings except Fig. 1 and 2 of Plate 30 and Figs. 21—23 of Plate 32.

Plate 30.

- Fig. 1. *Dirona picta* MACF., painted from life. 5:1.
 Fig. 2. *Dirona alboineata* MACF., painted from life. 5:1.

Plate 31.

Figs. 1—10, *Dirona picta* MACF.

- Fig. 1. Three median teeth from above. 220:1.
 Fig. 2. Three median teeth in side view. 220:1.
 Fig. 3. Median tooth in ventral view. 220:1.
 Fig. 4. Second lateral tooth, inner face. 220:1.
 Fig. 5. Mandibles from right anterior side. *w* wing. *h* hinge ligament. *m* masticatory portion. 12:1.
 Fig. 6. Inner face of left mandible. *w* wing. *h* hinge ligament. *c* chitinous band connecting the two mandibles. *m* masticatory portion. 12:1.
 Fig. 7. Outline of right mandible from external surface as seen by transmitted light to show the three thickened portions 1, 2, 3, radiating from and strengthening the hinge region.
 Fig. 8. First lateral tooth, dorsal view. 350:1.
 Fig. 9. First lateral tooth, ventral view. 350:1.
 Fig. 10. First lateral tooth, inner face. 350:1.

Figs. 11—19, *Dirona alboineata* MACF.

- Fig. 11. Two median teeth from above. 220:1.
 Fig. 12. Median tooth, side view. 220:1.
 Fig. 13. First lateral tooth from above. 220:1.
 Fig. 14. First lateral tooth, inner face. 220:1.

Fig. 15. First lateral tooth ventral view, the denticles concealed by the base. 220 : 1.

Fig. 16. First lateral tooth ventral view, the denticles visible. 220 : 1.

Fig. 17. Outer face mandible. *w* wing portion. *m* masticatory portion. *h* hinge ligament. 12 : 1.

Fig. 18. Inner face mandible. *w* wing portion. *m* masticatory surface. *h* hinge ligament. *c* chitinous band connecting the mandibles 12 : 1.

Fig. 19. Second lateral tooth, outer face. 220 : 1.

Plate 32.

Fig. 20. Reproductive system of *Dirona picta* MACF. The ducts have been spread out from their natural position to show their relations with each other. *ov. t* ovotestis. *h. d* hermaphroditic duct. *h. a* hermaphroditic ampulla. *x* point of division of hermaphroditic duct into the oviduct, and *v. d* the vas deferens. *p* preputium. *m* retractor muscle of preputium and glans. *a* atrium, receiving on its dorsal surface the duct of *s* the spermatheca. *a* albumen gland. *n* mucus gland. 13 : 1.

Fig. 21. Left Rhinophore of *Dirona albolineata* MACF. from behind and within. 9 : 1.

Fig. 22. Rinophore of *Dirona picta* MACF. from in front. 9 : 1.

Fig. 23. Clavus of Rhinophore of *Dirona picta* MACF. from behind. 9 : 1.

Fig. 24. Central nervous system of *Dirona picta* MACF. in dorsal view. *c* cerebral, *pl* pleural portions of cerebro-pleural ganglia. *p* pedal ganglia. *r. g* rhinophore ganglia. *c. 1* rhinophore nerve. *c. 2* second cerebral nerve, to mouth region and veil. *c. 3* third cerebral nerve, to mouth region and veil. *c. 4* fourth cerebral nerve. *c. 5* optic nerve, arising from the minute optic ganglion. *c* eye. *c-b. c* cerebro-buccal connectives. *pl. 1* first pleural nerve. *pl. 2* second pleural nerve. *p. 1* first pedal nerve. *p. 2* second pedal nerve. *p. 3* third pedal nerve. *p. p. c* parapedal commissure. *p. c* pedal commissure. *pl. c* pleural, or visceral commissure. *n. g* genital nerve; to its left the paired visceral nerves arising from the same commissure. *b.* buccal ganglia, removed from their normal position below the cerebral ganglia. *b. c* buccal commissure. The otic vesicle is seen close to the side of the cerebro-pleural ganglion, resting upon the antero-dorsal surface of the pedal ganglion. 28 : 1.